Office of Naval Research

Advanced Integrated Radar Electronics and Photonics – AIREP

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Outline

- Objective
- Background
- System Architecture
- Sub-systems
- Demonstration

Objectives

- Develop Advanced Sub-systems and capabilities for Mountaintop Testbed for airborne platforms
  - E-2C, UAV, Potential MMA
- Areas of Consideration
  1. Lightweight Low Cost UHF Transmitter
  2. Transmit and Receive Switch
  3. Lightweight Low Cost UHF Digital Exciters
  4. Lightweight Low Cost UHF Digital Receivers
  5. Advanced UHF electronically scanned antenna
  6. Lightweight Low Cost CEC Airborne Active Antenna
  7. Circular Space Time Adaptive Processing
  8. Advanced and novel ideas for UHF radar system monitoring
  9. Mountaintop concept demonstration testbed radar and communications support equipment
  10. Simulated Synthetic Radar Environhment

Radar and Avionics Sub-Systems

Sub-Systems	Proposed
Antenna	UESA (UHF/IFF/SATCOM/ES) Multi-Channel UHF Antenna, T/R Swt/LNA IF/RP (Stationary Dome)
Transmitter	Multi-Channel Tube Uniform Power Modules, Power Supplies (Sized for 24 Channels), Structure
Exciter	Multi-Channel Digital Exciters Digital Phase and Amplitude Control
Receivers	Multi-Channel Digital Receivers Digital Beamformer Hardware Equalization, Pulse Compression, Pre Doppler Processor
Processors/ STAP	Multi-Channel Post-Doppler STAP Single STAP, Digital Beamformer, Signal, Detection, Data, Environmental Processor
CEC Active Antenna	C-band Active Antenna Exceeds CEC Antenna Gain Requirements Smaller, Lighter, More Affordable
Simulated Synthetic Env	Simulated Synthetic Radar Environment on Makaha Ridge & MHPCC
Advanced System Monitoring	Advanced and novel ideas for UHF radar system monitoring

AIREP Program Overview

PHASE 1
FY99 – FY06

Increasing Threat Sophistication

Mountaintop Test Bed (MTB)
Makaha Ridge, PMRF

Non-Real Time Demo (MRF-03)
Real Time Demo (MRF-05)
Transitioning to E-2C SIL

PHASE 2
FY03 – FY06

Sub-System Development (SSD)

Optimized Radar Architecture Trade-off Study

Demo New technologies & Insert Subsystem Prototypes:

- Optimized Antenna
- Miniaturized Digital Receivers
- High Power Tube Transmitter
- Next Generation Exciter
- Circular STAP Algorithm
- Advanced CEC Antenna

PHASE 3A/B
FY 04 – FY07

3A: Flight Demo (FD)
3B: E-2C SIL

E-2 Insertion

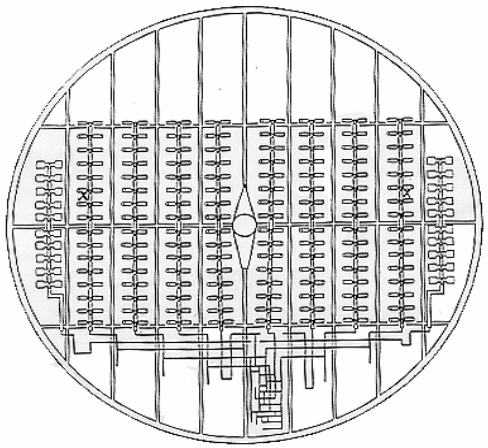
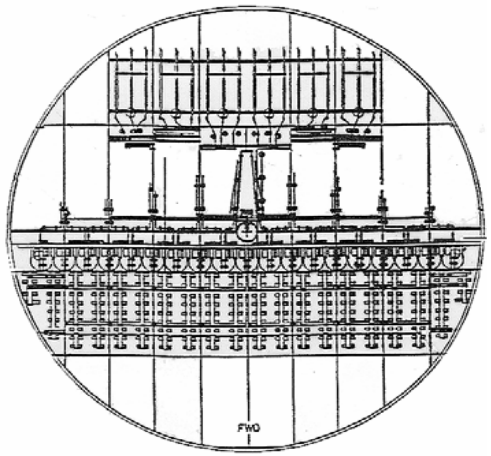
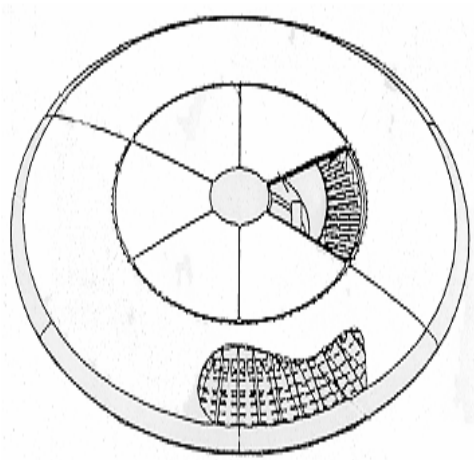
Validate System Concept

Flight qualified prototype subsystems demonstrated:

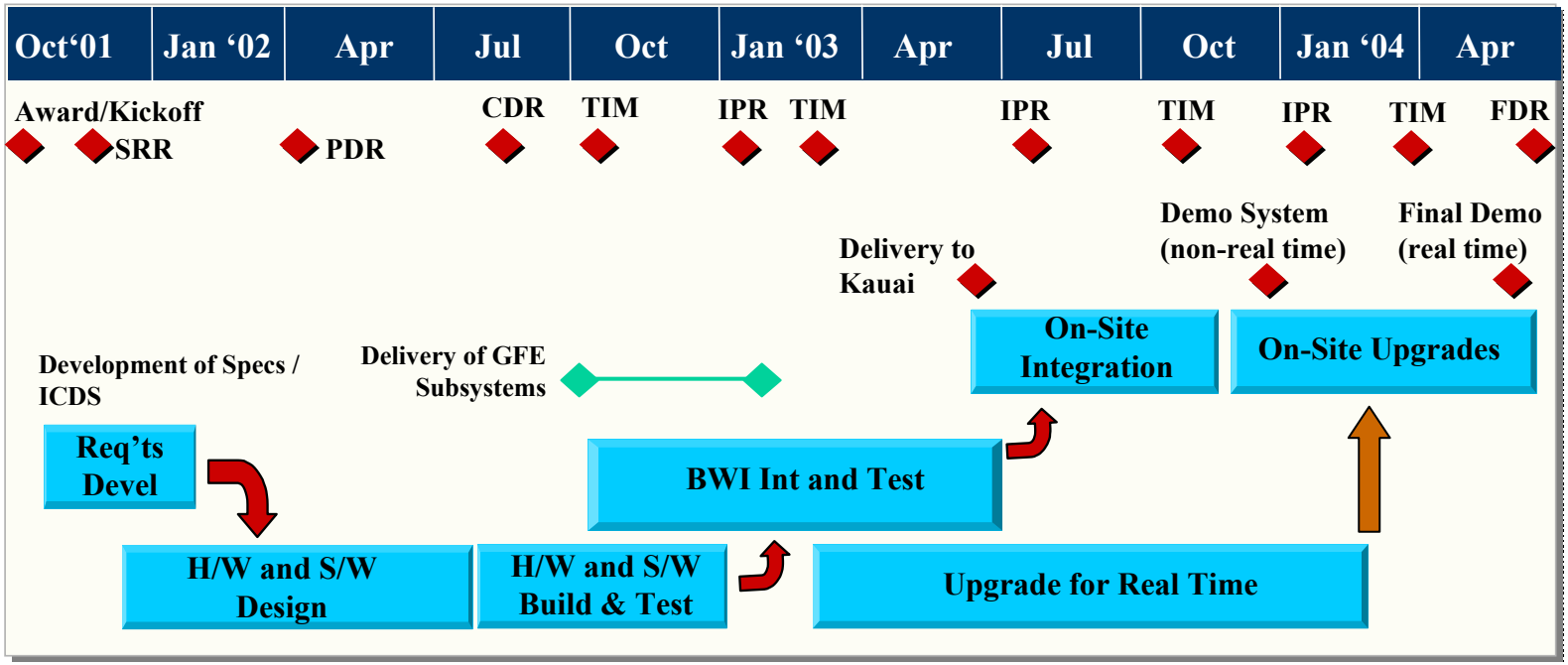
- Prove flight worthiness
- Demo in flight conditions
- CONOPS demonstration

Each phase reduces risk for development of advanced technology for potential E-2C AH insertion

Surveillance Radar Antenna Evolution…

TRAC-A, E-2C Group II	*RMP ADS-18S, Hawkeye TBD*	*UESA-54, Hawkeye TBD*
Mechanical Scan	**(Hybrid)** **Mechanical-Electronic Scan**	**Electronic Scan**
		
Support fleet operations in broad ocean area: ➢ Single fixed beam in rotating dome ➢ Limited coverage ➢ 1970's RF & structures technology	**Provides limited ocean & land capability:** ➢ 120 degrees rotating & ESA coverage ➢ Search & track in lockdown ➢ 1980's technology	**Enhanced ocean & land operations capability:** ➢ 360 degree Beam on Demand capability ➢ Fixed Radome with continuous search & track ➢ FY '00 Navy ATD ➢ 1990/2000's Technology

UESA Radar Test Bed (RTB) Schedule/Milestones

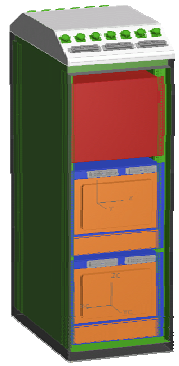


Key Milestones :

- *Program/Kickoff Award: Oct 2001*
- *SRR : Dec 2001*
- *PDR : April 2002*
- *CDR : August 2002*
- *Delivery to MR : June 2003*
- *Demo Non Real time : December 2003*
- *Demo Real Time : May/June 2004*
- *IPRs/TIMs to be held bi-annually*

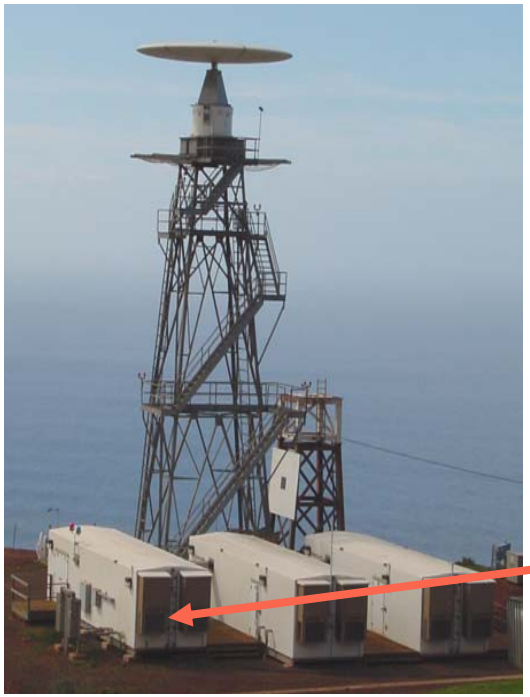
UESA RTB System
Non-Real Time Demo August 03, MRF 03

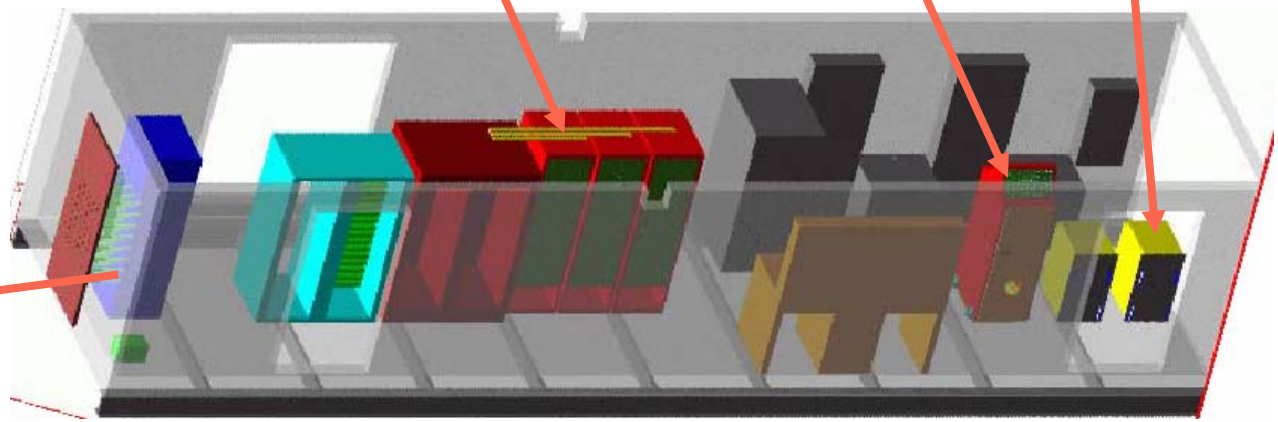
54 Channel Uniform SiC Transmitter (No Power Combiners nor Circulator/ Receive Protect)



54 Channel Digital Exciter/ Receiver

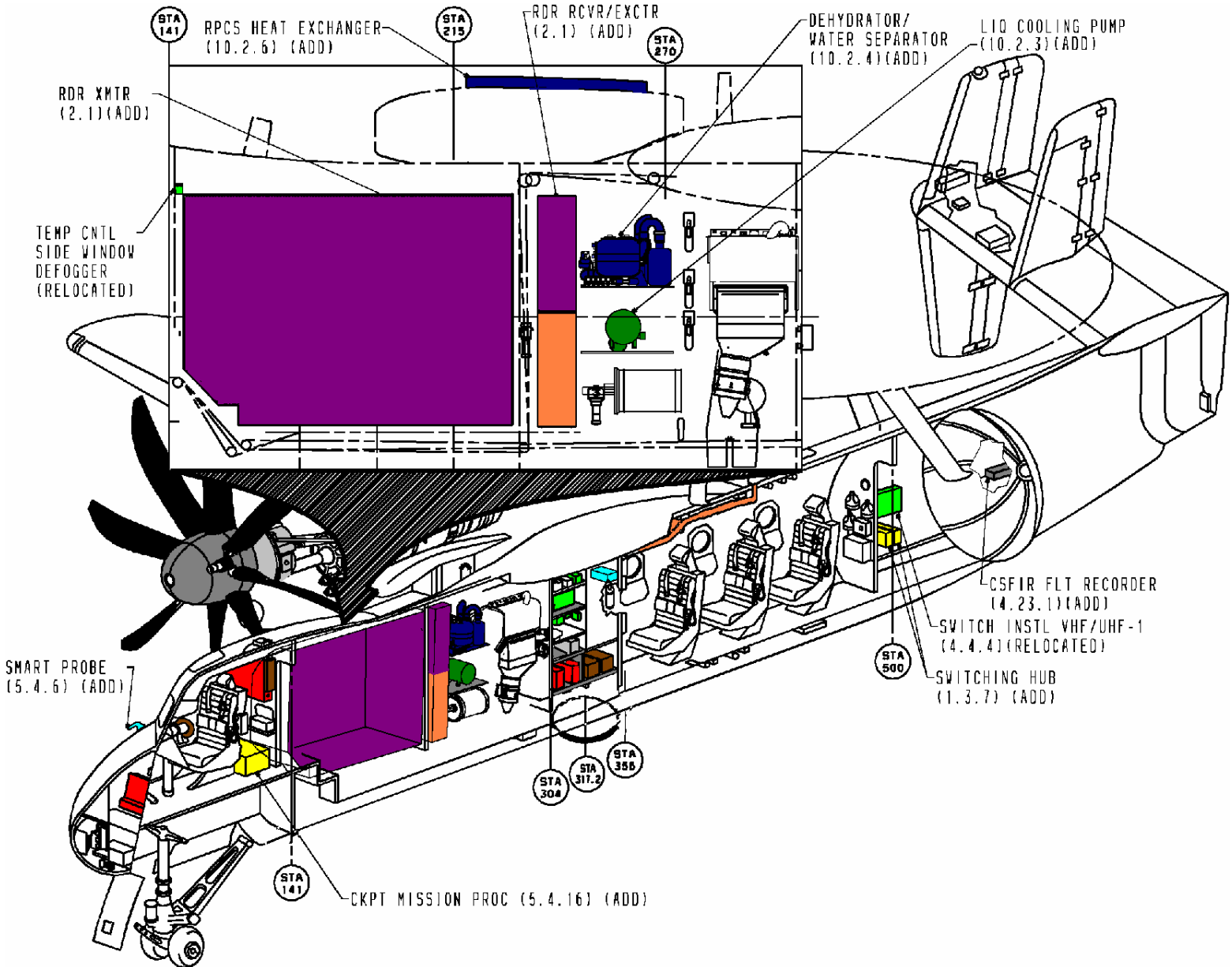
27 Channel STAP Processor



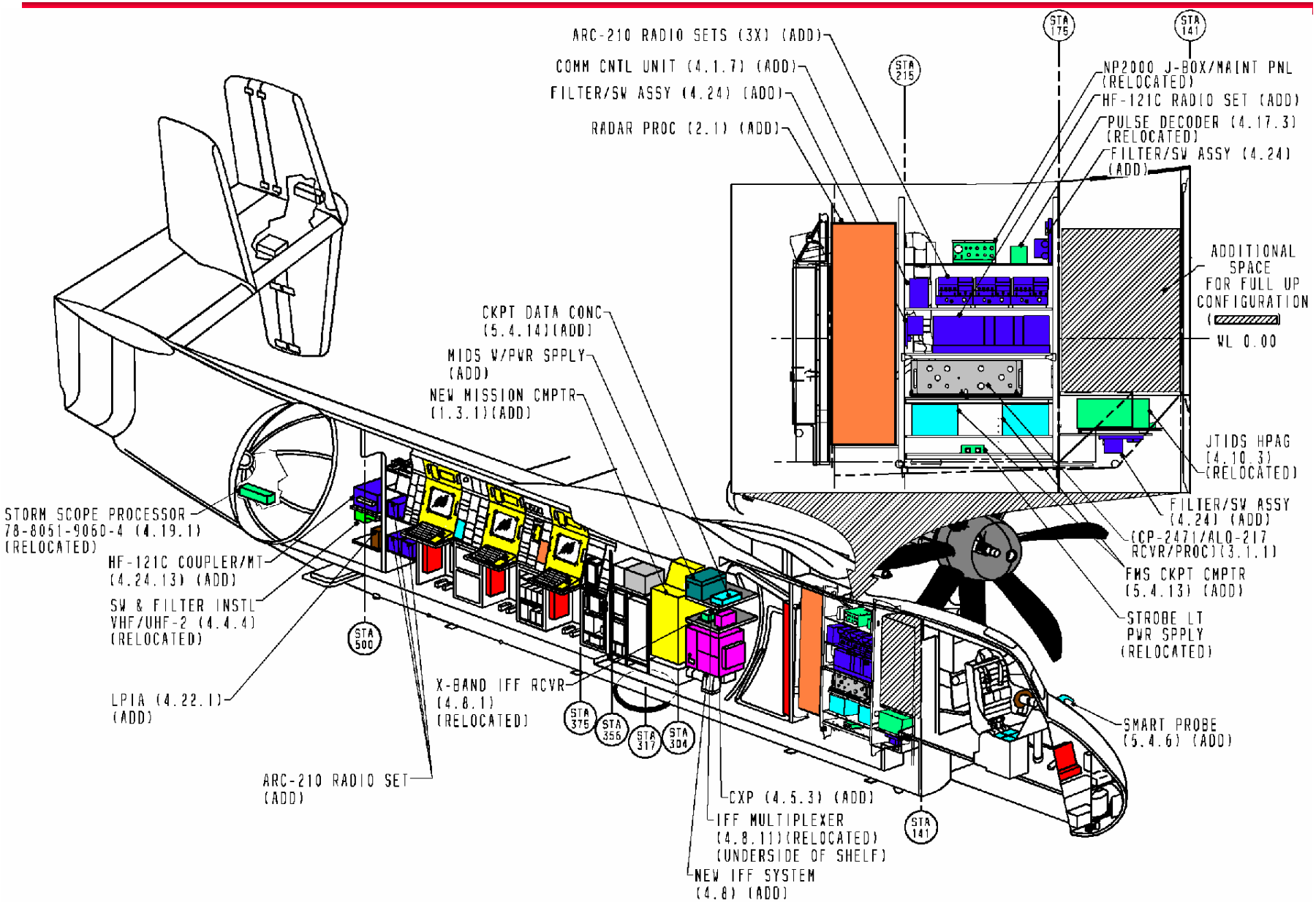


UESA RTB Trailer

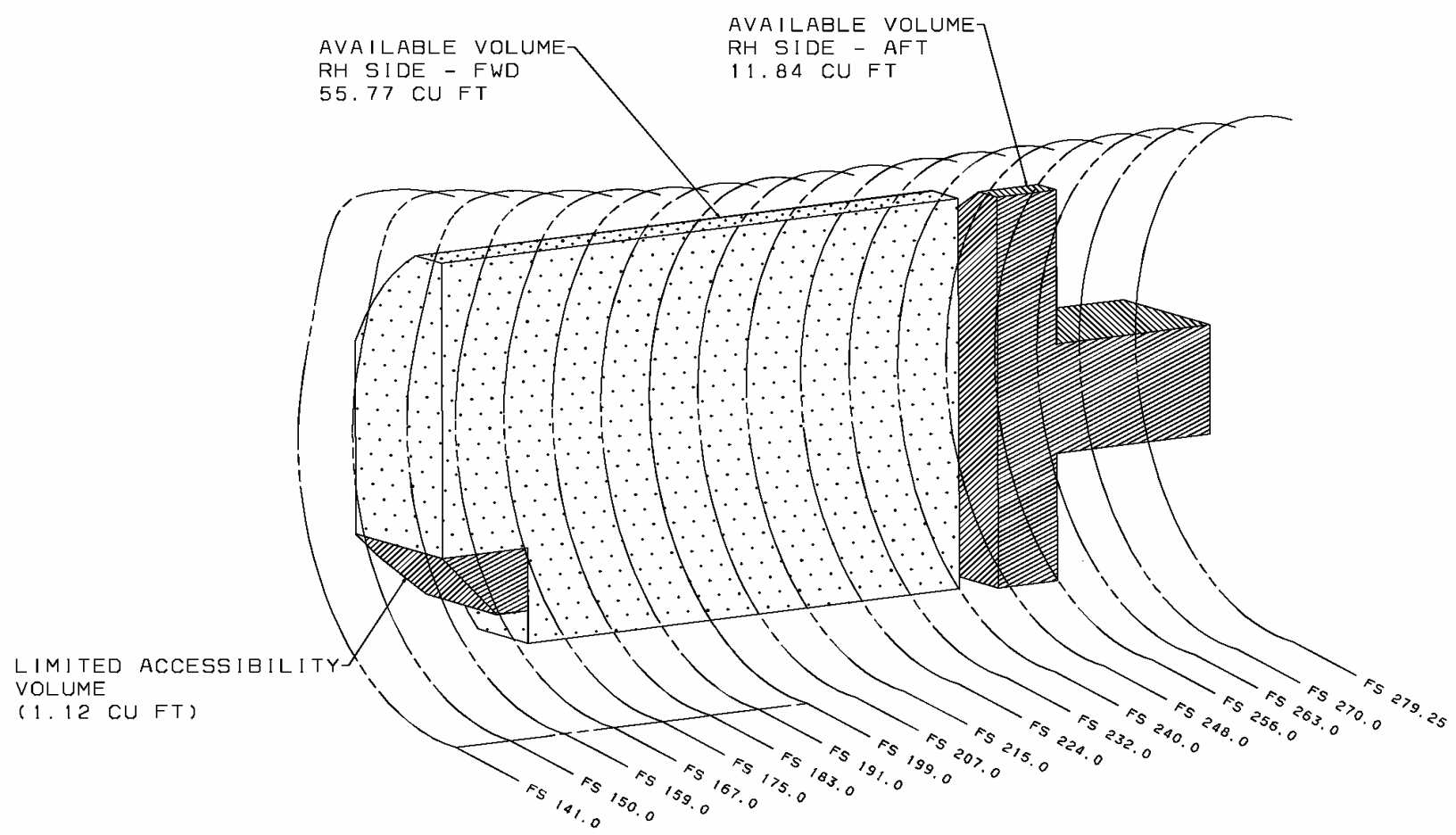
E-2C AH Right Side



E-2C AH Left Side

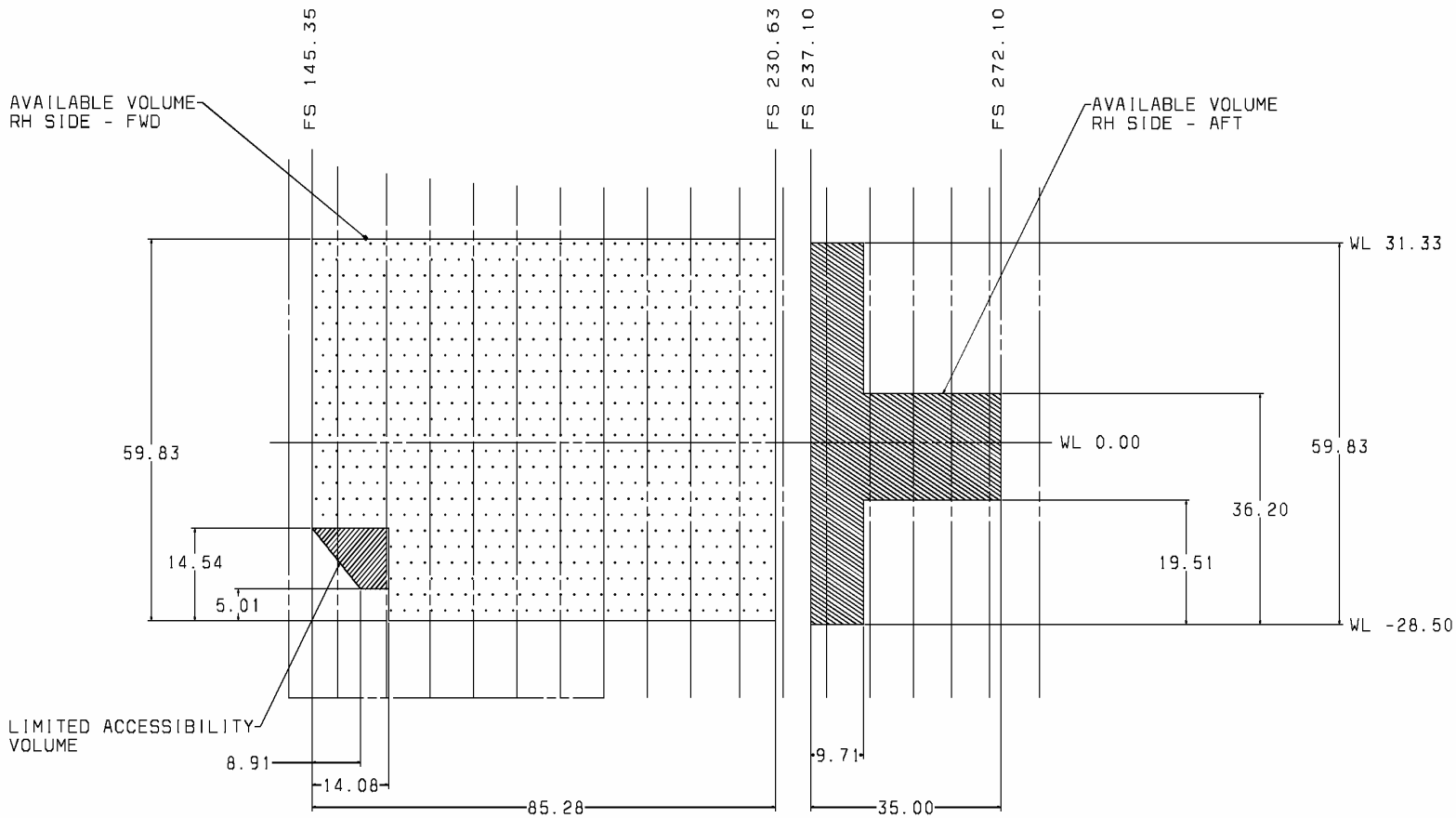


Max Envelope Definition – Right Side



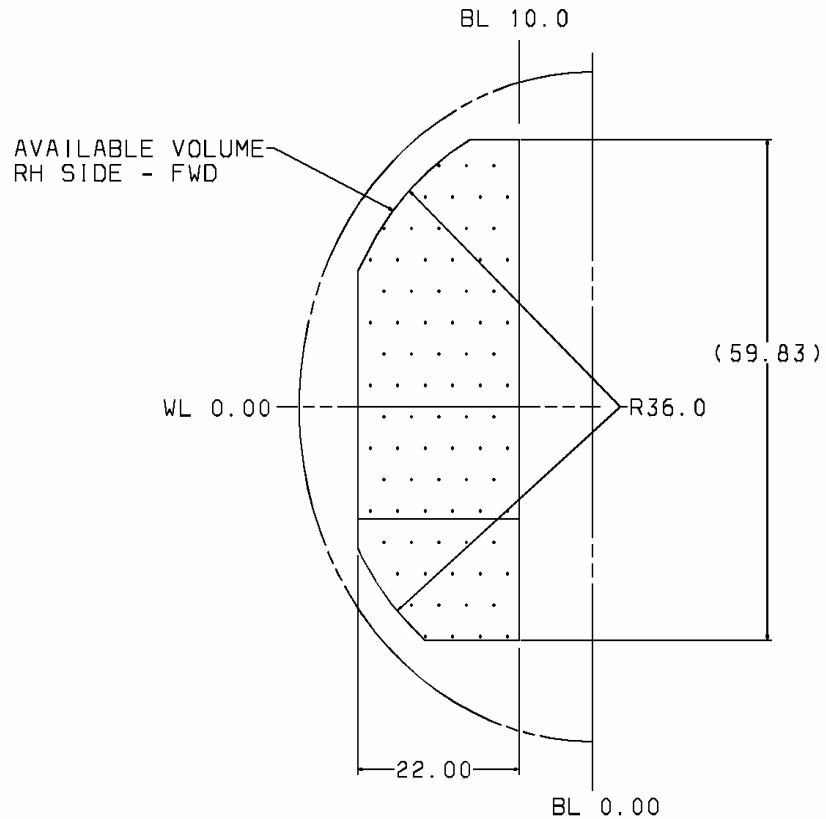
ISOMETRIC VIEW – RH SIDE

Max Envelope Definition – Right Side

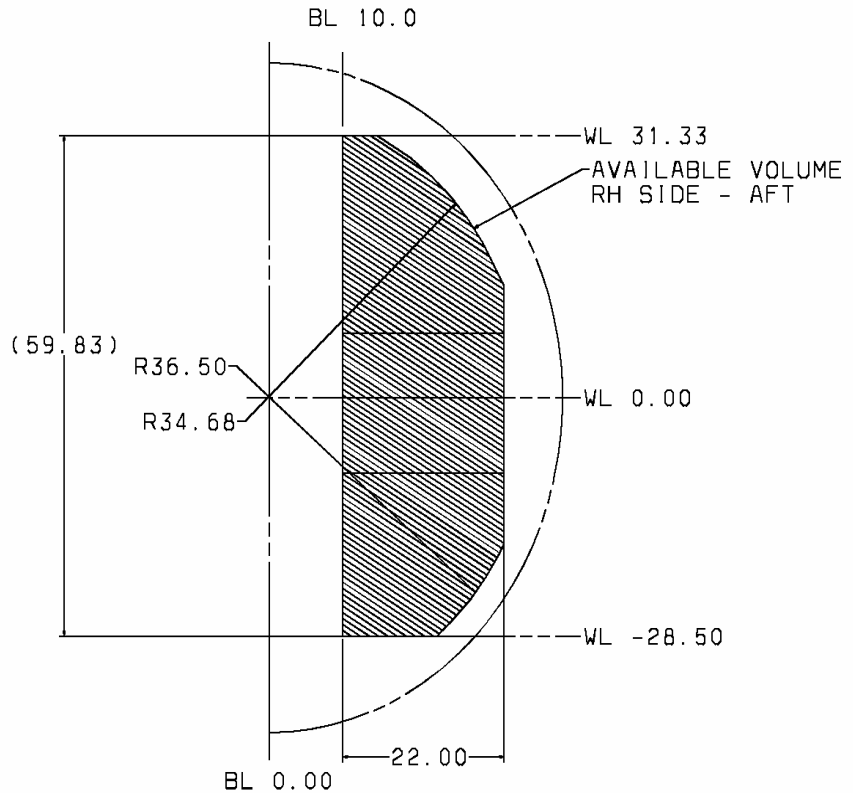


VIEW LOOKING OUTBOARD – RH SIDE

Max Envelope Definition – Right Side

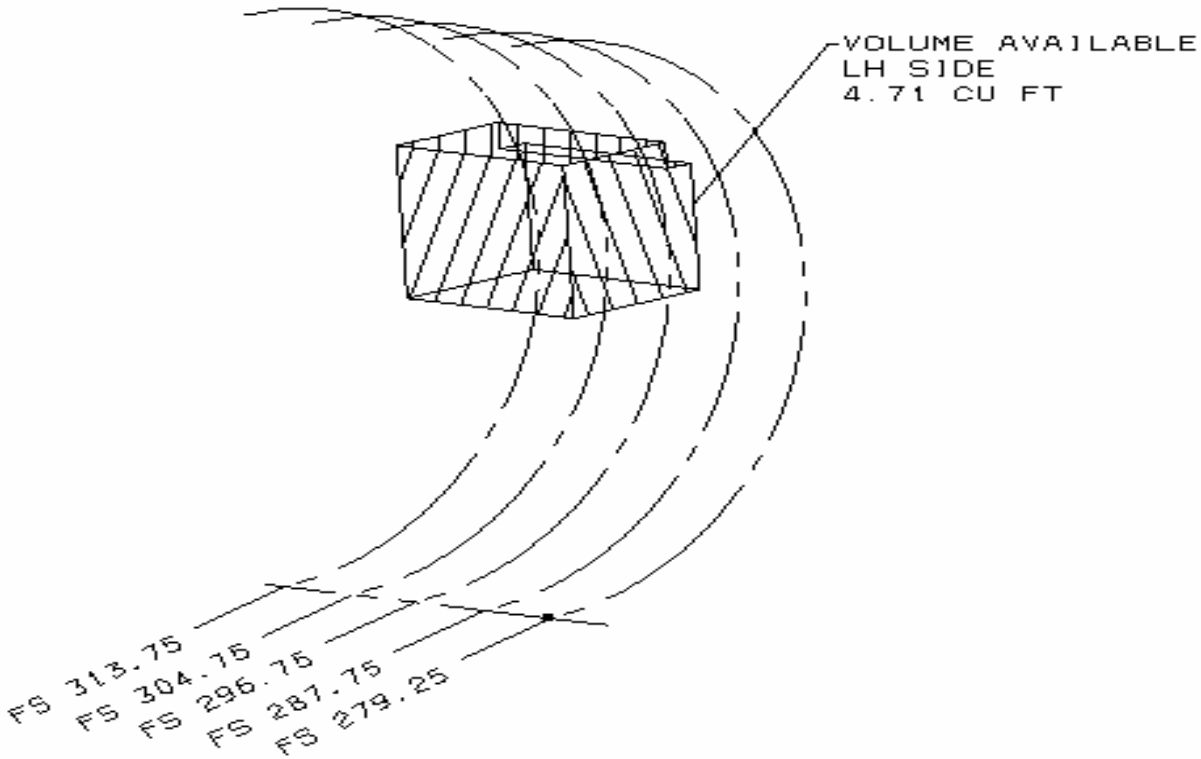


VIEW LOOKING AFT – RH SIDE



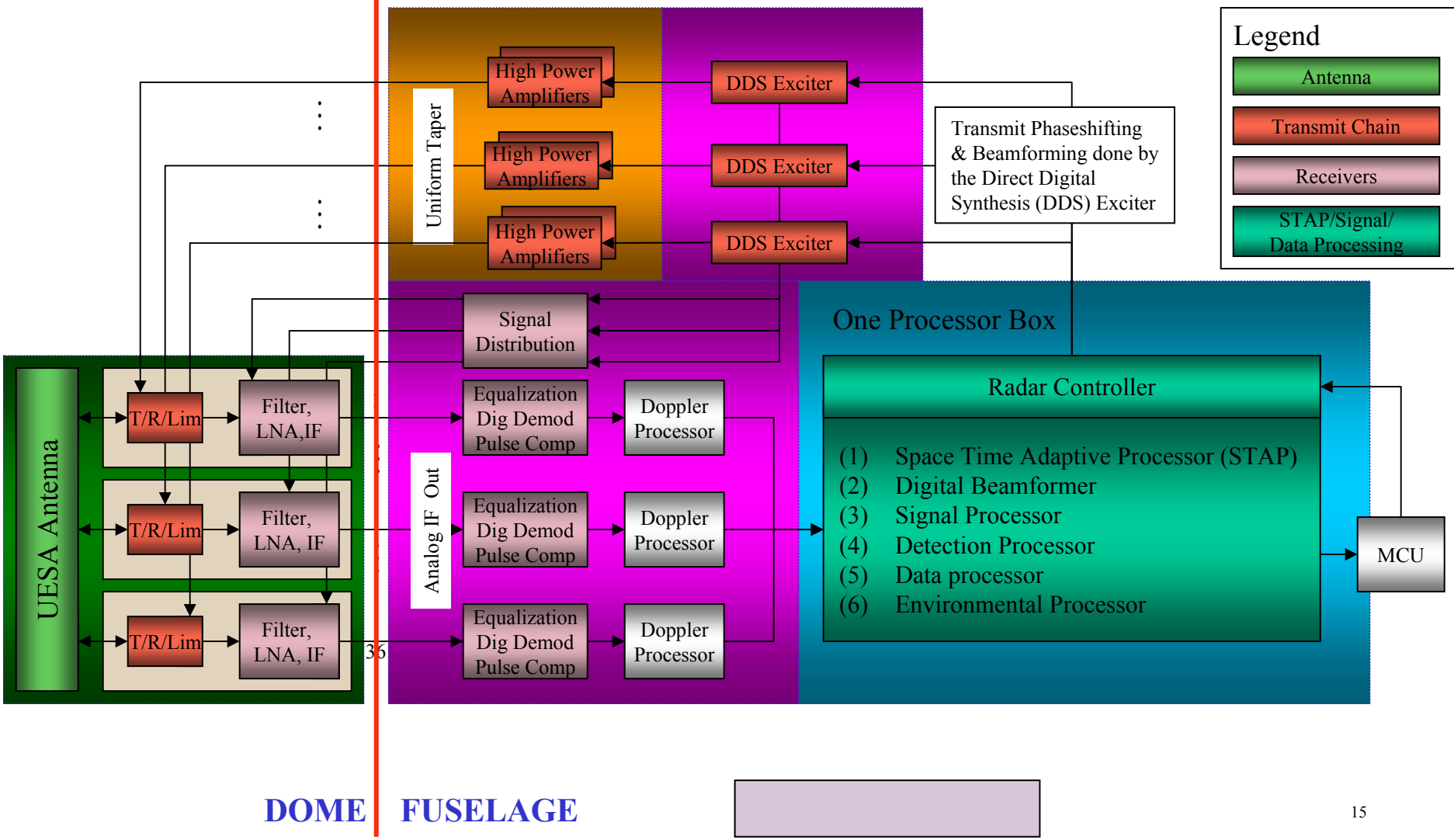
VIEW LOOKING FWD – RH SIDE

Max Envelope Definition – Left Side

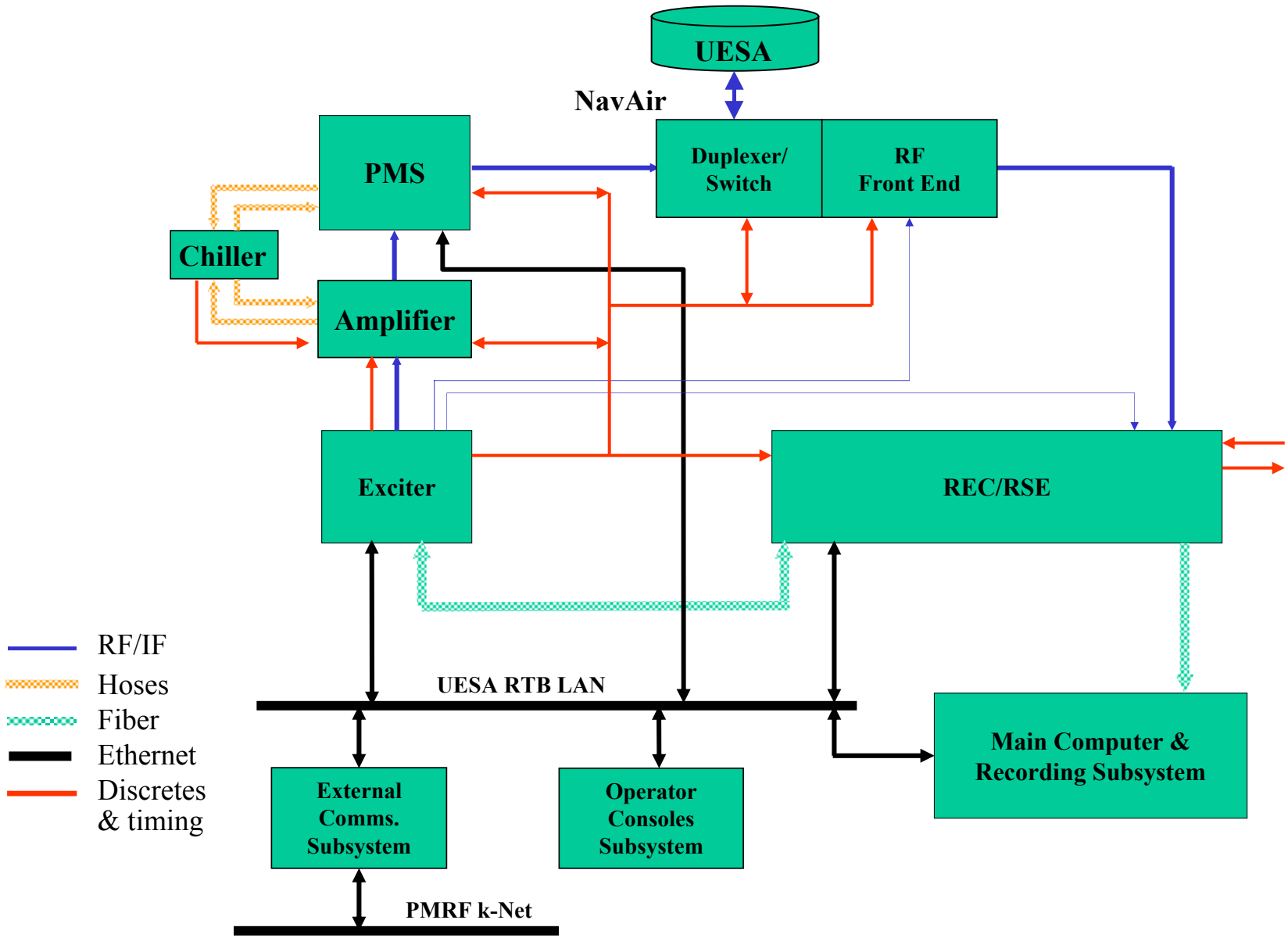


ISOMETRIC VIEW
LH SIDE

Optimized AIREP Architecture



Current UESA RTB Block Diagram

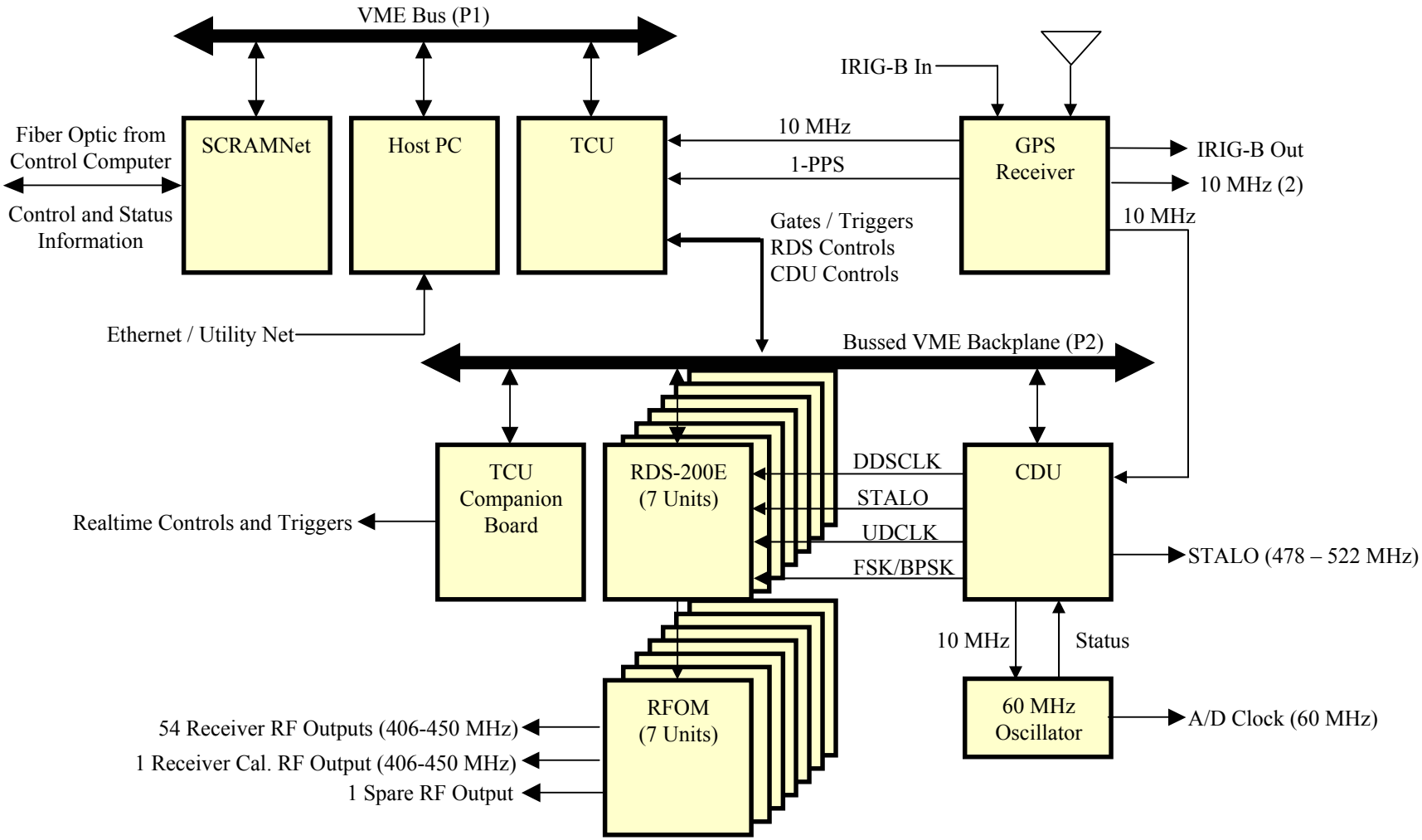


Exciter Subsystem

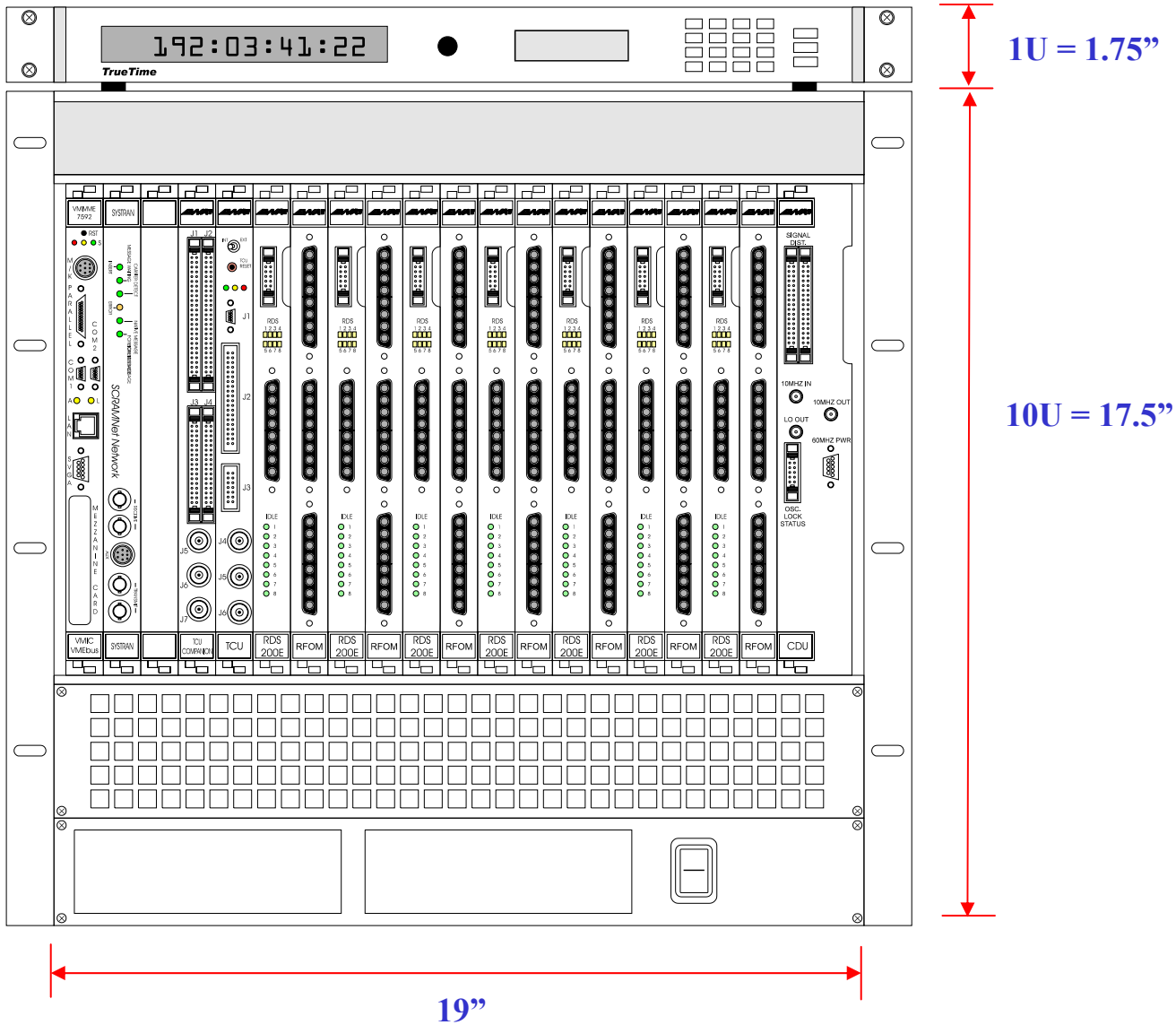
Features

- Latest DDS technology
  - Analog Devices AD9854
- Modular
  - All hardware on VME boards
    - except 60 MHz A/D Clock
- High Performance
  - 32-bit frequency resolution
  - 14-bit phase resolution
  - 12-bit amplitude resolution
- Maintainable
  - Easy access cabling
  - All I/O on chassis rear panel
- Cost Effective
  - COTS
  - Built on Existing Designs
- Transmit beam steering and forming
  - Supports both LUT and ALG methods
- 56 independently controlled DDS channels
  - 54 RF transmit channels
  - 1 receiver calibration channel
  - 1 spare channel
  - 54 receiver inputs for future growth (i.e. simulated targets)
- Modulation: BPSK, PSK, FSK, Linear and non-linear FM
- 10 MHz GPS Reference (4x)

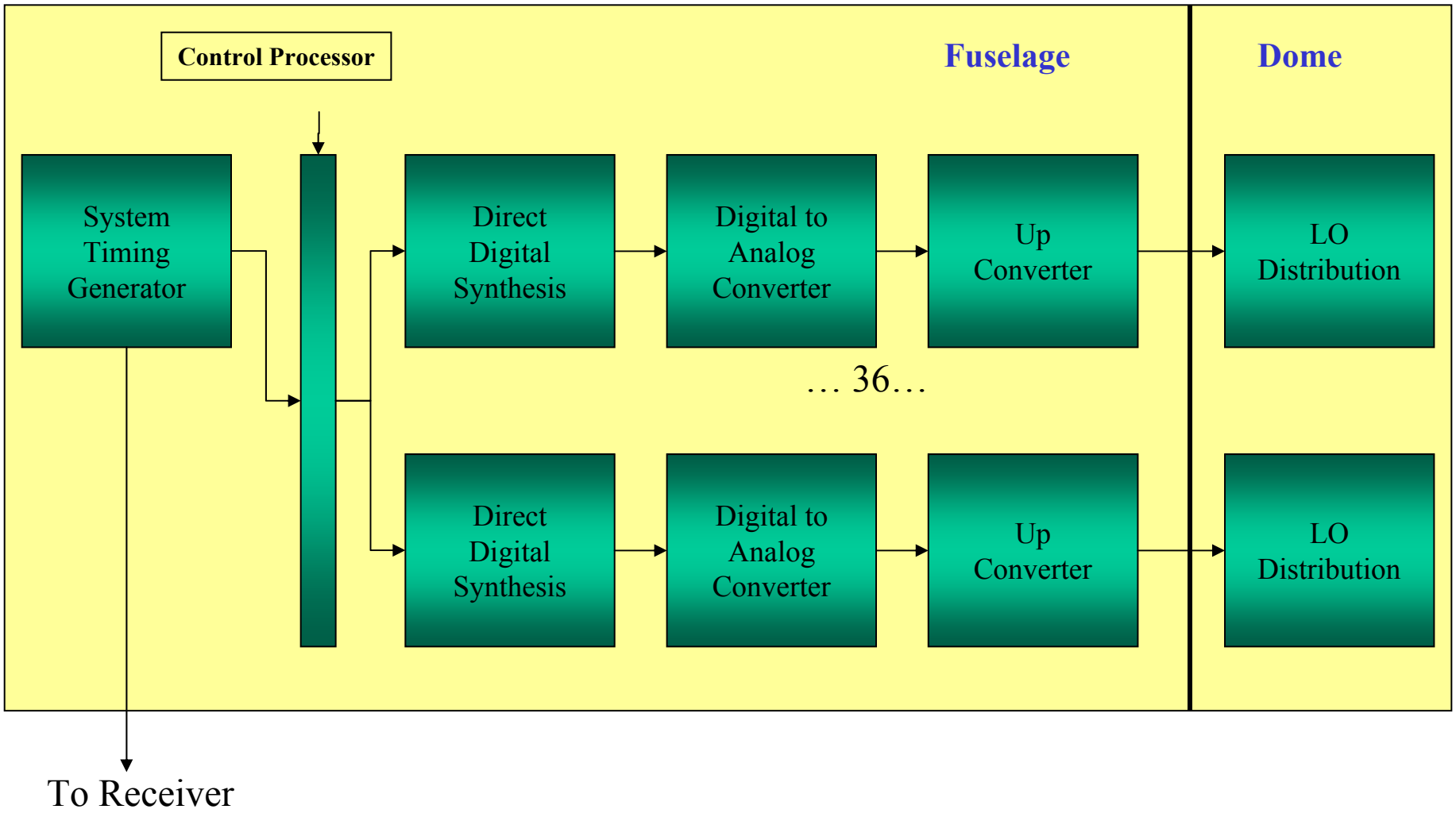
Exciter Block Diagram



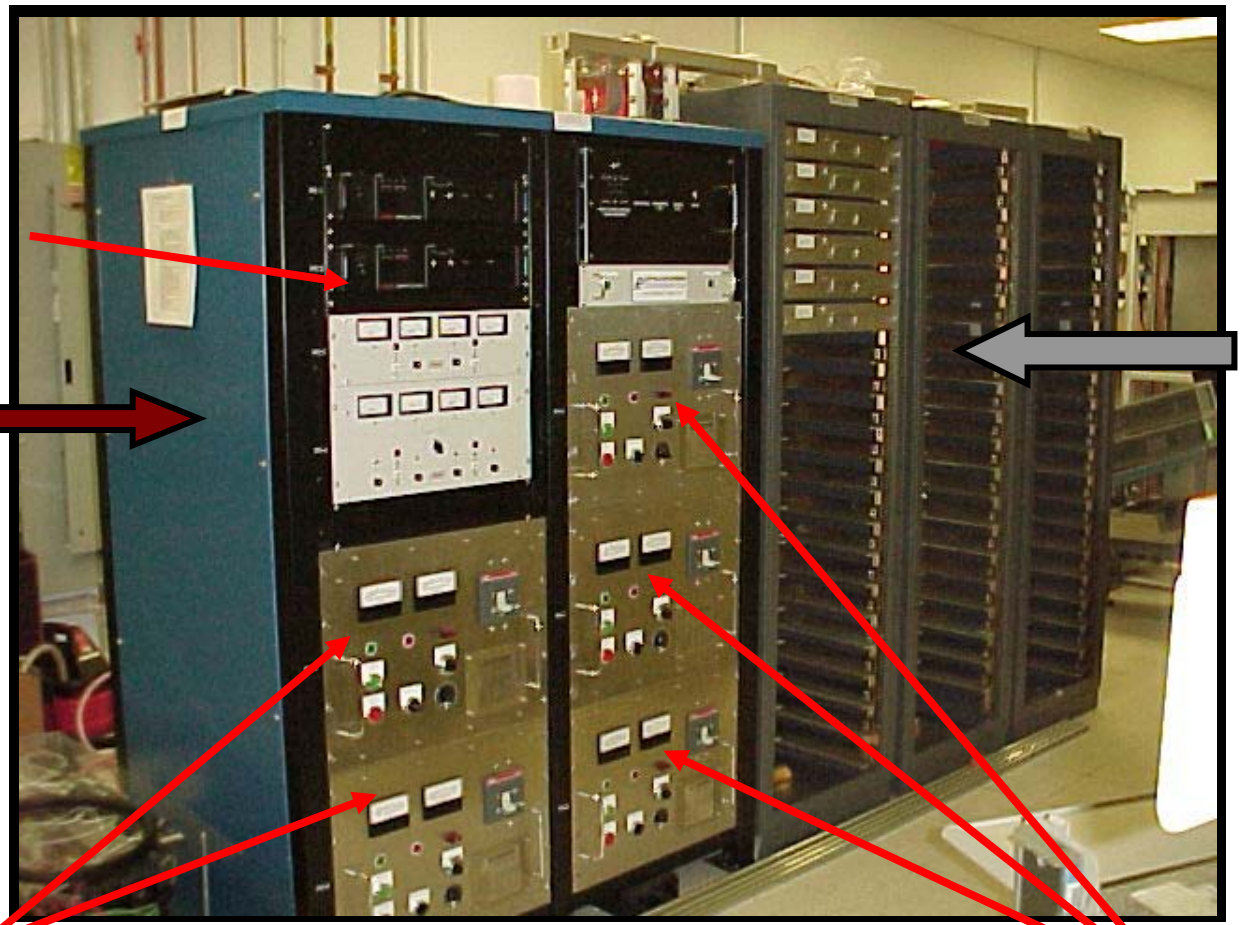
Exciter Configuration



Direct Digital Synthesis (DDS) Exciter



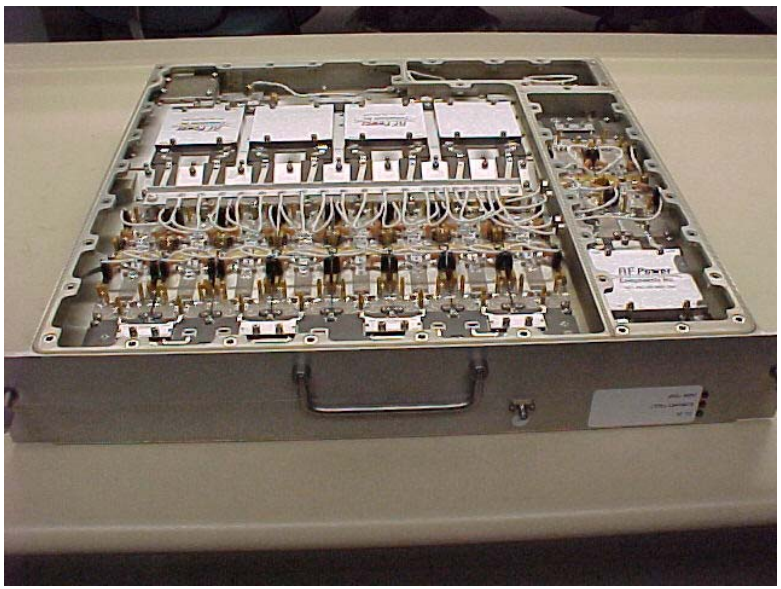
Current SiC Transmitter Subsystem

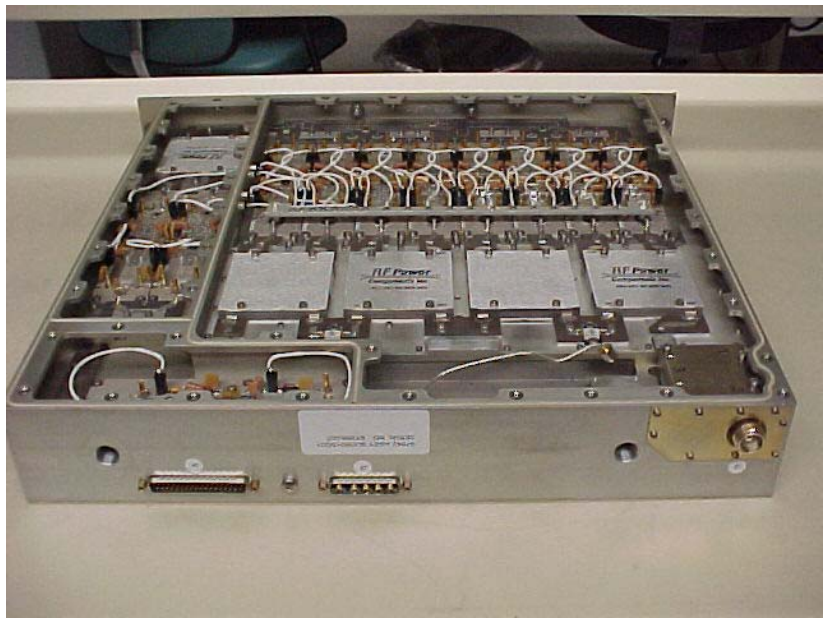


- Inputs from Exciter – front
- Outputs to Duplexer – rear

PAM – Power Amplification Module

- **Input side – receives signal from Exciter**





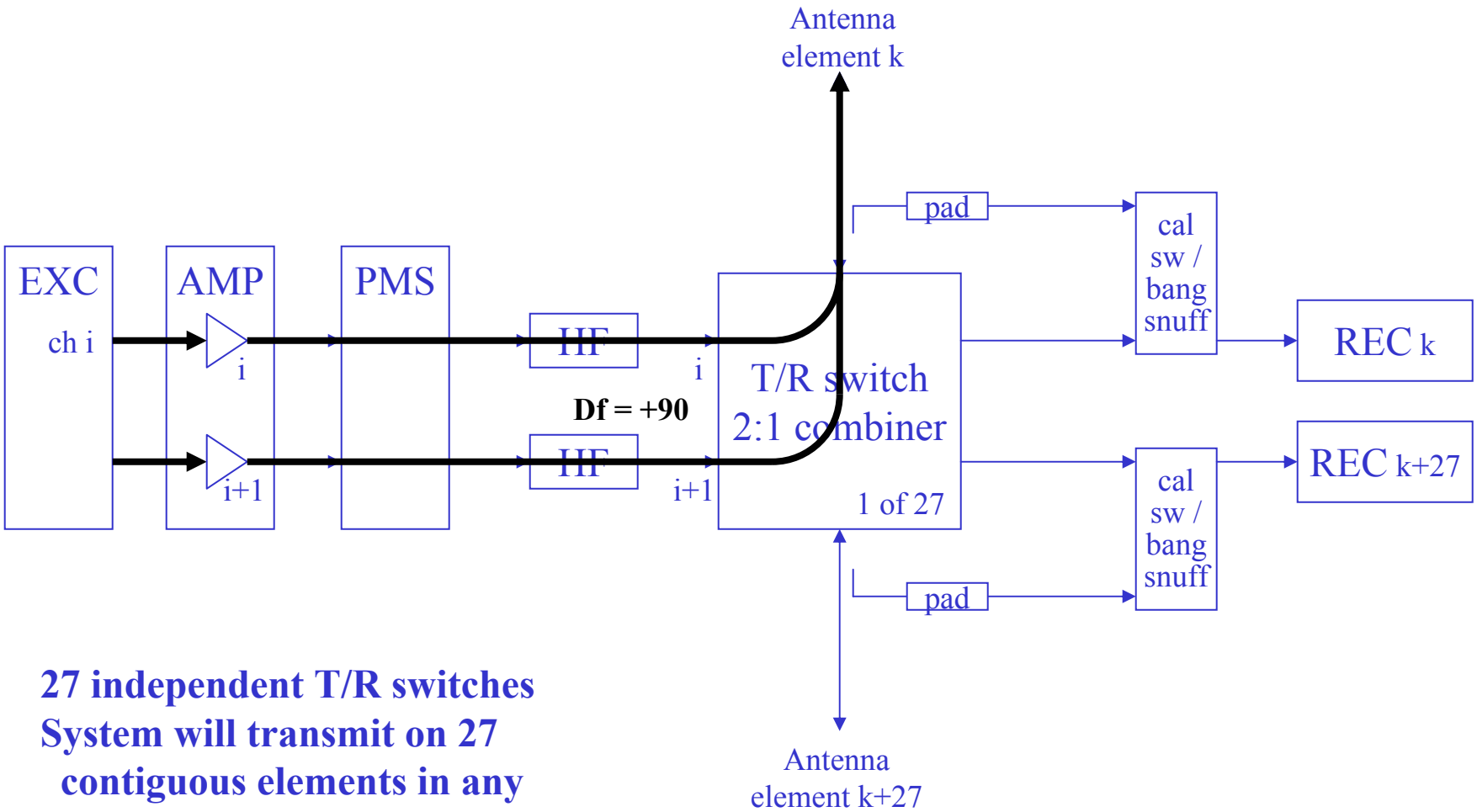
- **Output side – sends signal to PMS**

Power Monitor Subsystem

Features

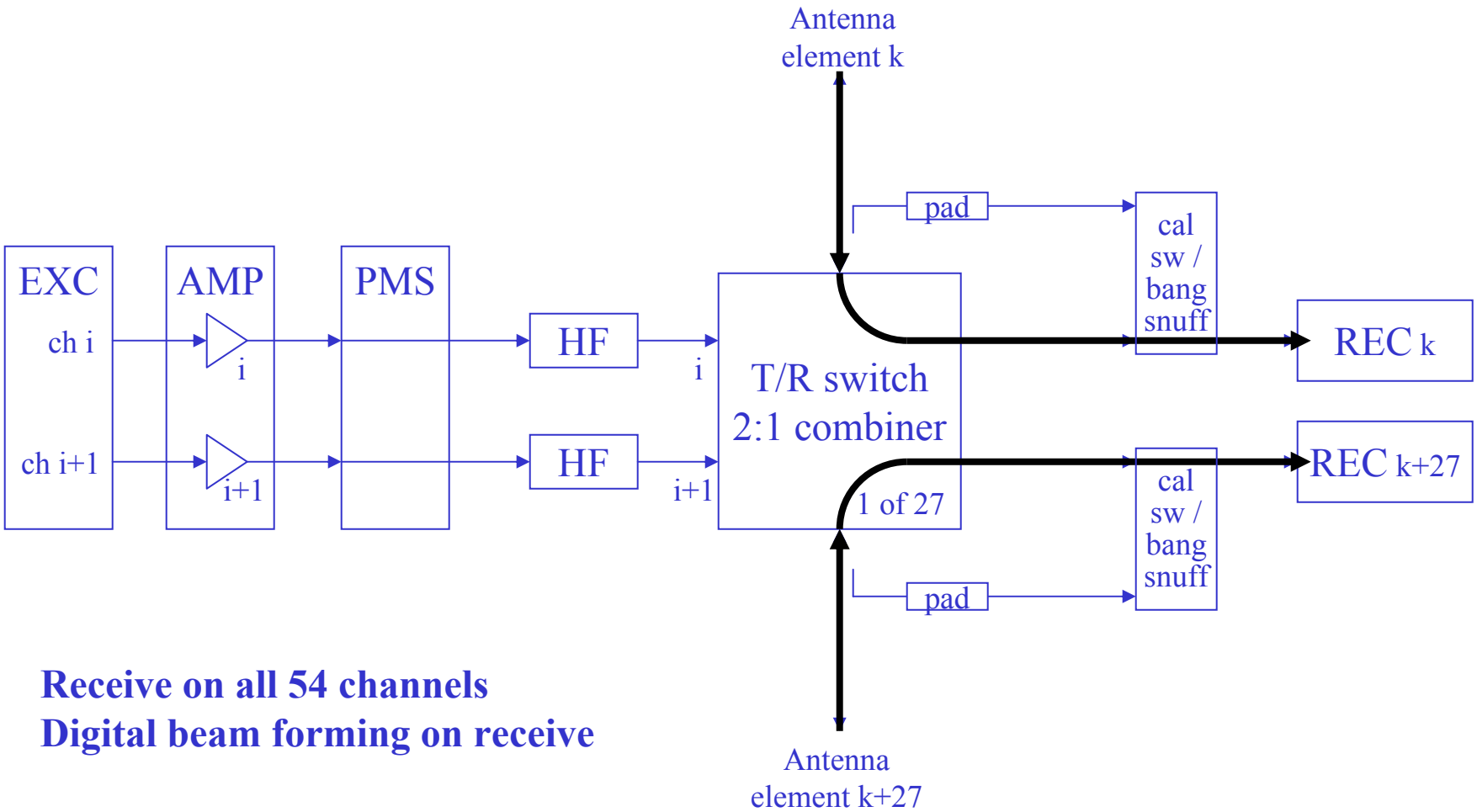
- **Input**
  - 54 channels from Transmitter
- **Output**
  - 54 Channels to T/R switch subsystem
  - 54 Channels to Dummy Load subsystem
  - Transmit disable signal to Transmitter subsystem via RSE

Transmit Path



27 independent T/R switches
System will transmit on 27 contiguous elements in any direction

Receive Path

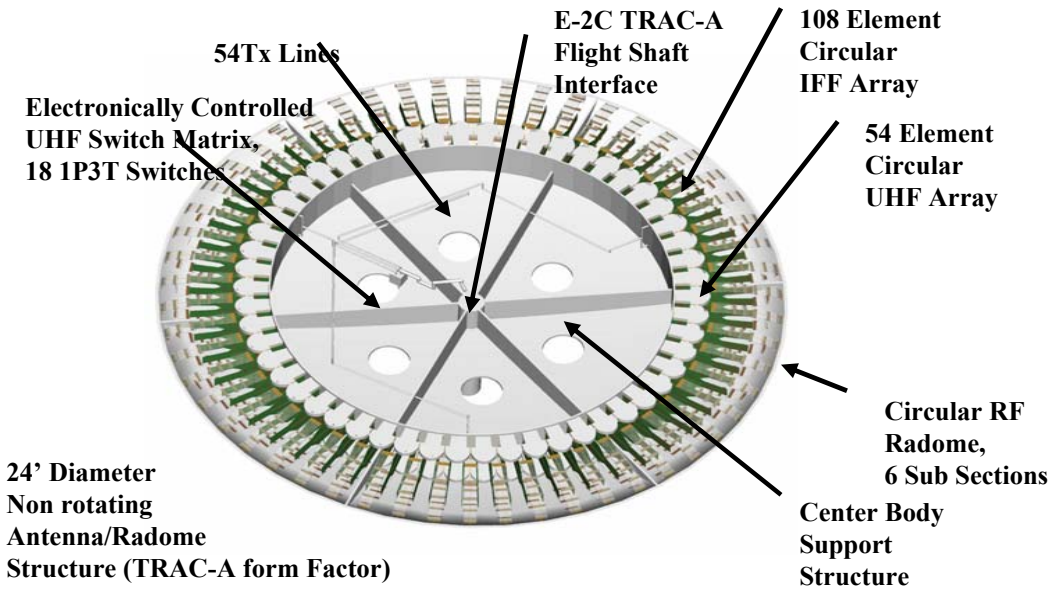


Receive on all 54 channels
Digital beam forming on receive

UESA Antenna Evolution

NAVAIR ¼ Scale array (1999)

Raytheon Full Scale Array (1996-99)

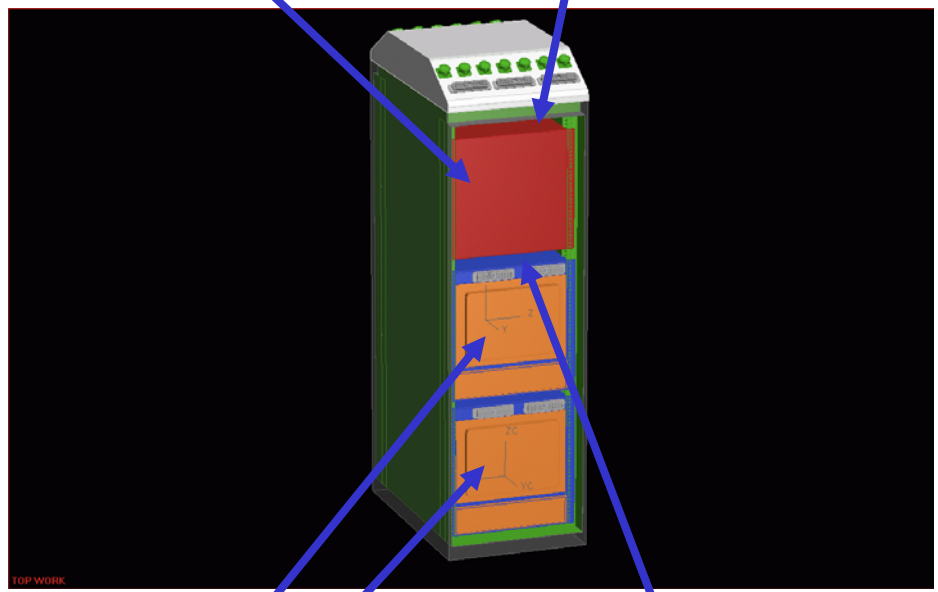


Raytheon Full Scale Array (2000-2002)

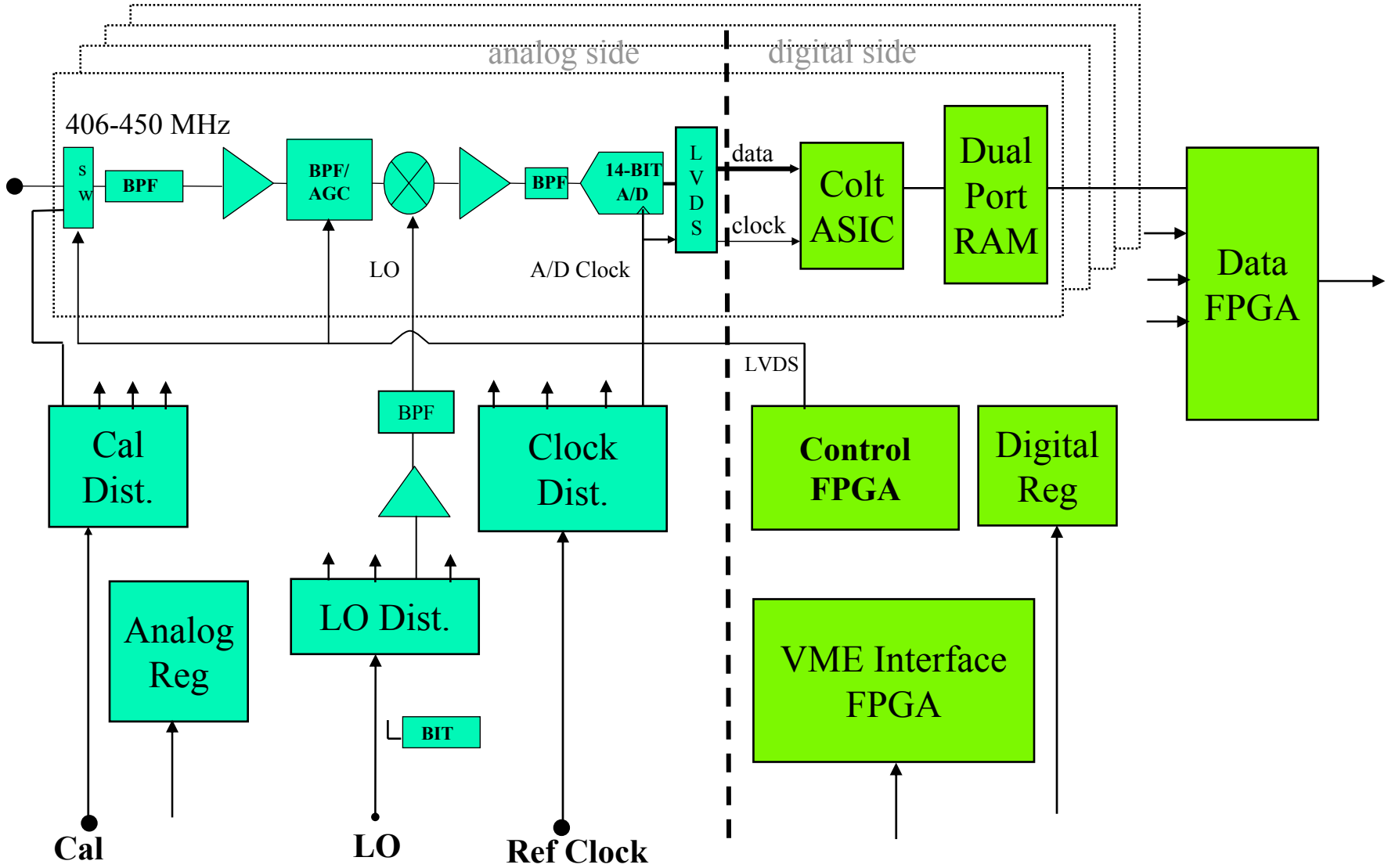
Radar Support Electronics Subsystem

Features

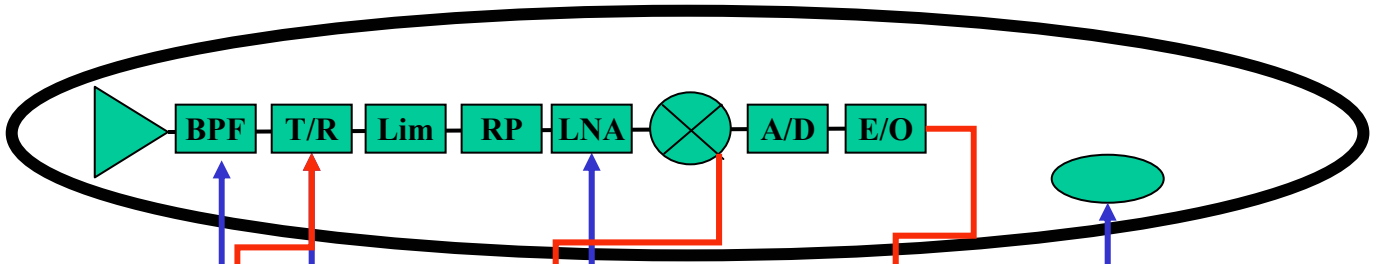
- GPS
- Exciter
- 1st Stage LO/CLK/BIT dist
- RSE 1 (master)
- RSE 2 (slave)
- EMI-shielded 19” rack
- All interfaces at top of rack
  - Doghouse provides easy connector access
- 54 channels I/Q data



UHF Receiver Block Diagram



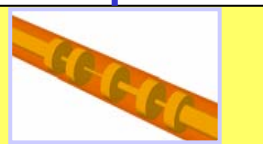
Integrated Analog Receiver Front-End

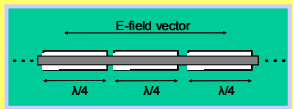


TX in

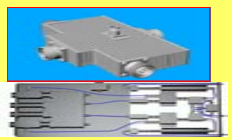
RX (IF) out
(Near Term)

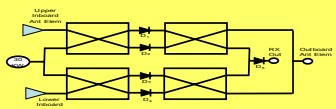
RX Digital
Fiber Optic out
(Far Term)





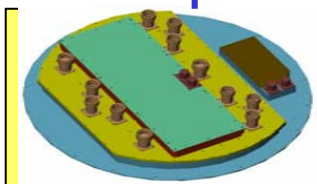
Integrated
Cable Band
Pass Filter





Low Loss Miniature
T/R Switch &
Limiter

LNA: MTBF
1.1 Mil Hours
NF: <1 dB
Gain: ~40



T/R Switch &
RCVR Analog
Front-End Access
Plates (Total of 18)

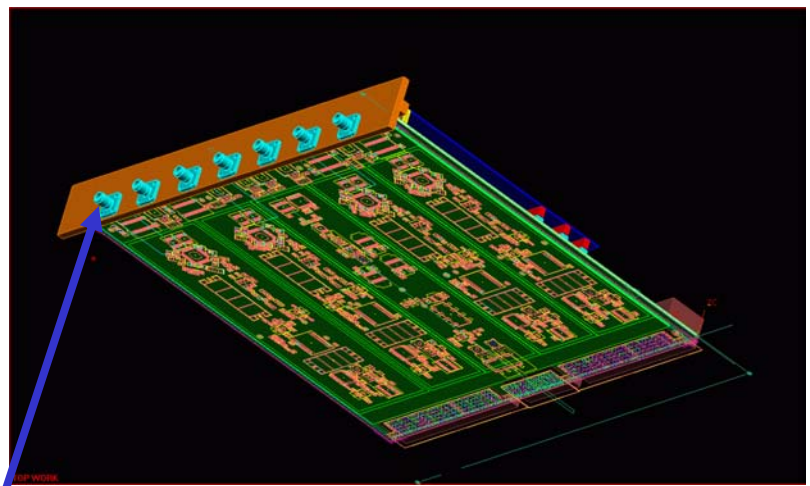
UHF Receiver Board

Features

- Two – sided, analog/digital design
- Digitizes incoming receive data
- Outputs data to MCR via VME backplane and Data I/O board (fiber outputs)

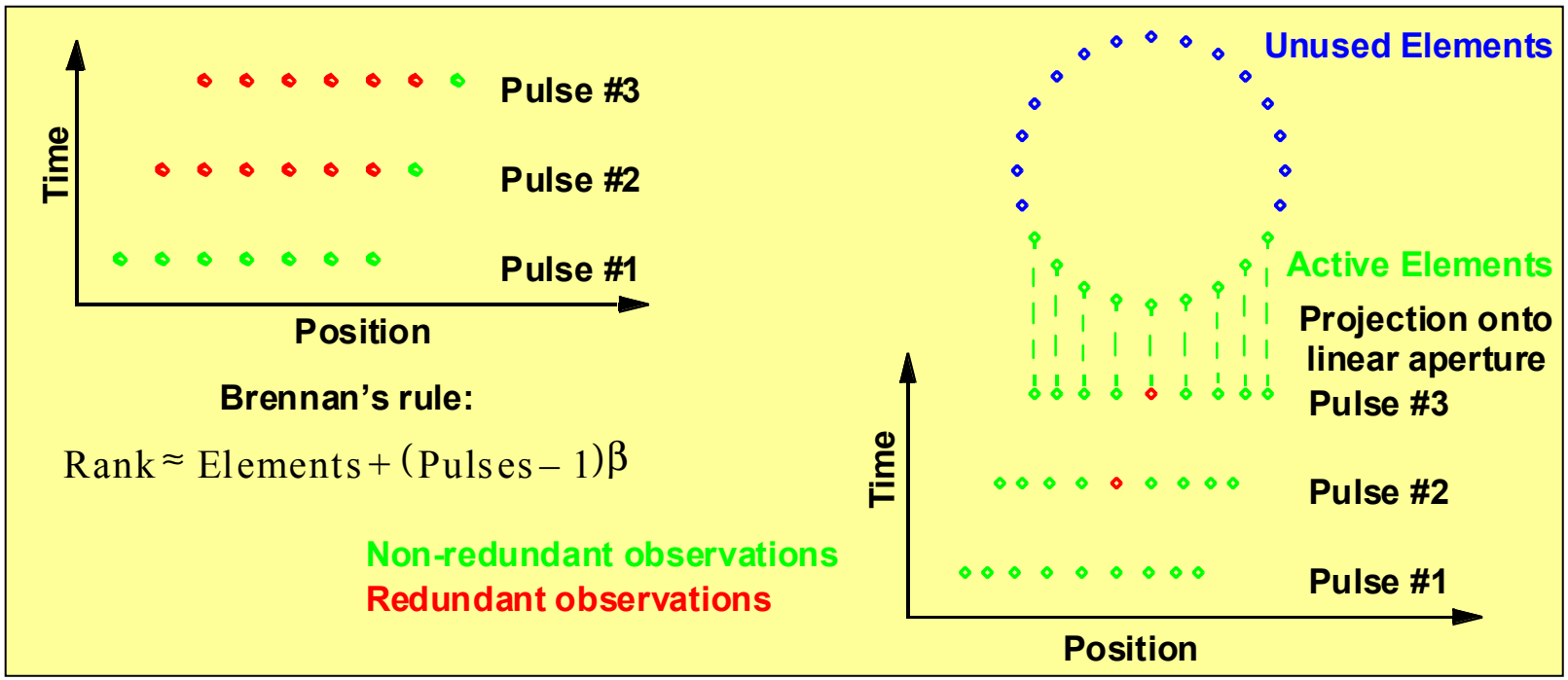
UHF Digital Receiver (UDR) Baseline

UDR



Rx, LO, CLK, BIT Inputs

Why UESA STAP is More Computational (Reason 2)

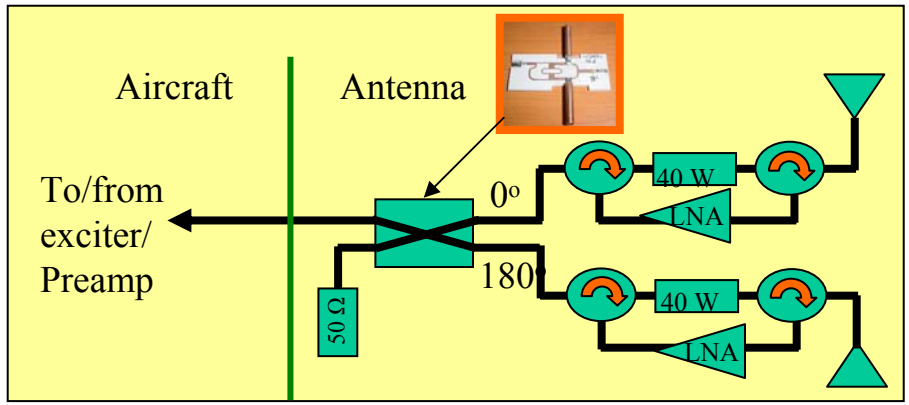


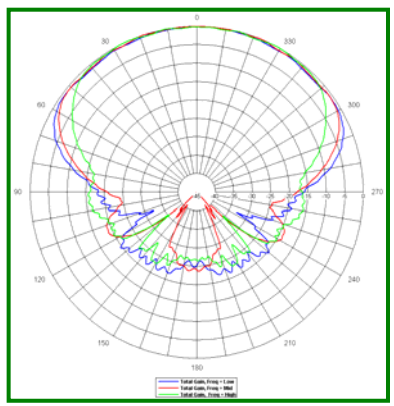
- STAP relies upon the redundancy of a linear array moving in space
- A circular array is less redundant
- AIREP needs low-sidelobe Doppler filtering before STAP to filter out some of the unwanted

Airborne CEC Active Antenna

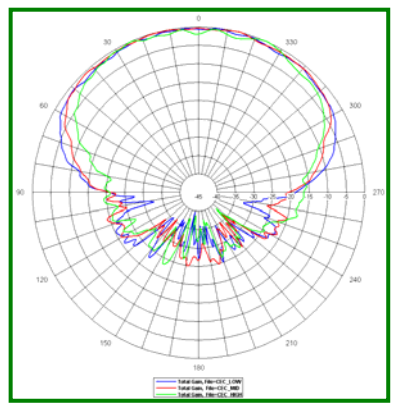
- Built and measured Passive Antenna
- Aperture for existing data distribution system
- 72-element circular array (electronic scan)
- For use with 24-channel or single channel Microwave Power Module based Transmitter
- 34" Diameter, 2.5" thick
- Weight: 24 lbs (w/out radome)
- Gain: 23 dBi (5° x 23° nominal) (measured)

Active Element Transmit/Receive Module





Modeled patterns



Measured patterns (super element)

Proposed AIREP Program

Phase 1: AIREP Mountaintop Test Bed (MTB)(FY02 – FY 05)

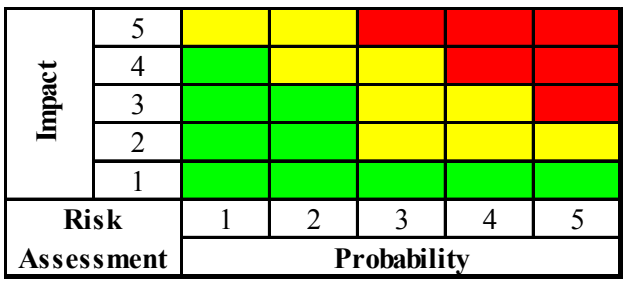
- **Non-Real Time Demo (MRF 03) (Funded)**
- **Space Time Adaptive Processing (STAP)**
  - **STAP Algorithm Dev**
  - **STAP Analysis at MHPCC**
- **Real Time Demonstration**
  - **Radar System Software**
  - **Optimized Sub-System Integration**
  - **Signal Processor Integration**
  - **Real Time STAP Implementation**
  - **Radar Demonstration (MRF 05)**
- **IFF/SATCOM/ES Integration**

Phase 2: AIREP Sub-System Development (SSD) (FY03 – FY 05)

- **Optimized Antenna**
- **Transmitter**
- **Receiver**
- **Exciter**
- **Active CEC Antenna**
- **Photonics Technology**

Risk Assessment (Cost, Schedule, & Performance)

Sub-Systems	AIREP System	MT Demo	Flight Demo
Antenna	UESA (UHF/IFF/SATCOM/ES)	6	7
Transmitter	Multi Channel Uniform	6	7
Exciter	Multi Channel Digital Exciters	6	7
Receivers	Multi Channel Digital Receivers	6	7
Processors/ STAP	Multi Channel Post-Doppler STAP	6	7
CEC Antenna	Active Antenna	6	7
Photonics	Digital/Fiber Optics Receive I/Q	6	7
Optimized UESA Radar	Real Time Demonstration of an Optimized System	6	7



Technology Readiness Level (TRL)

1. **Basic principles Observed & Reported**
2. **Technology Concept and/or Application Formulated**
3. **Analytical & Experimental Critical functions and/or characteristic proof of Concept**
4. **Component and/or breadboard validation in laboratory environment**
5. **Component and/or breadboard validation in relevant environment**
6. **System/subsystem model or prototype demonstration in a relevant environment**
7. **System prototype demonstration in an operational environment**
8. **Actual system completed and "flight qualified" through test and demonstration**
9. **Actual system "flight proven" through successful mission operations**

AIREP: Schedule/Milestones

NAVAIR

Phases and Tasks	Schedule																							
	FY02				FY03				FY04				FY05				FY06				FY07			
Phase 1 AIREP MTB																								
Non-Real Time Demo (MRF 03)																								
STAP Development																								
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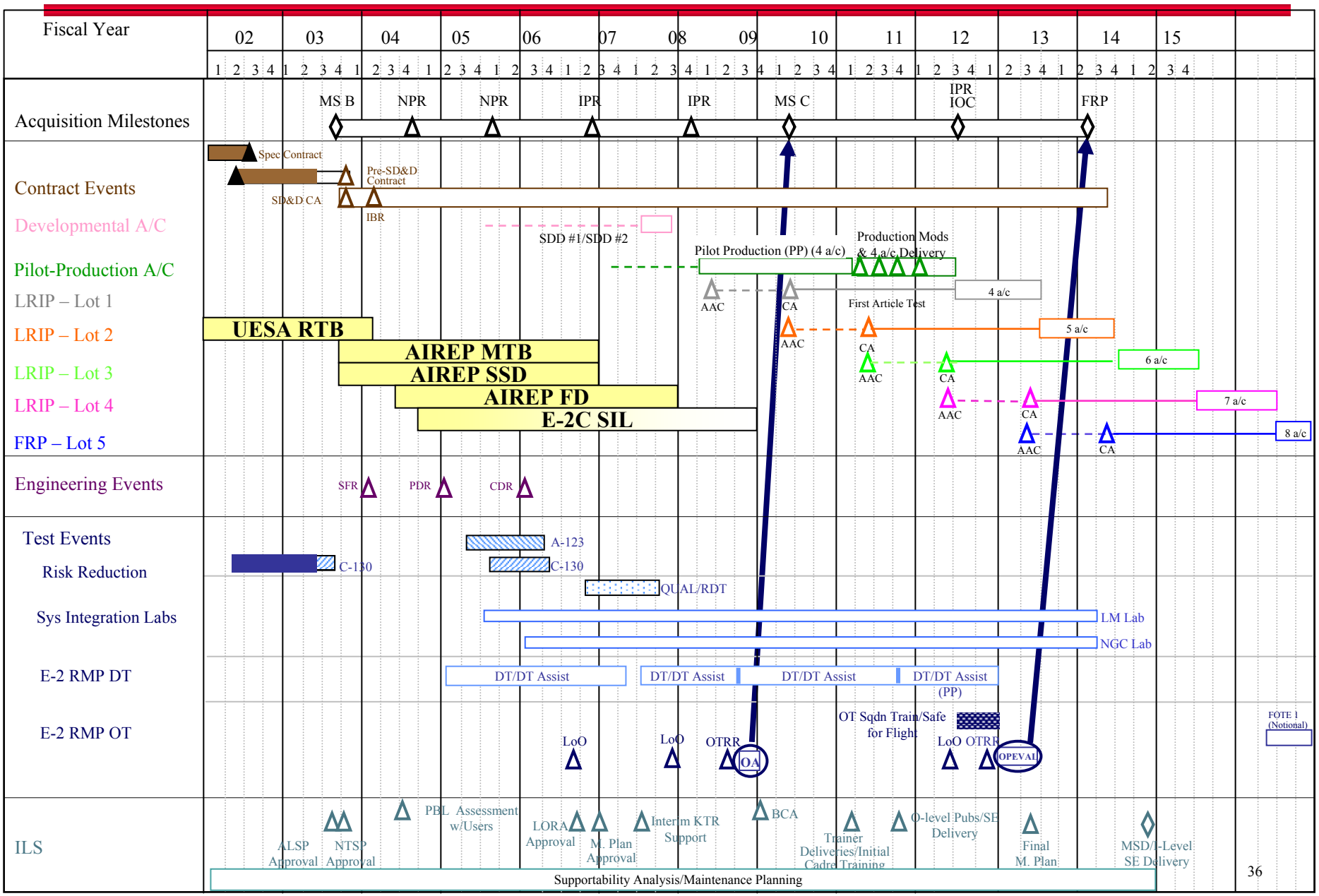
Phase 2: AIREP SSD																								
Antenna																								
Transmitter																								
Receiver																								
Exciter																								
Active CEC Antenna																								
Photonics Technology																								
Phase 3A: AIREP FD																								
Concept Development																								
Sub-system Flight Certification																								
System Integration																								
Flight Demonstration																								
Data Anlaysis																								
Phase 3B: E-2C SIL																								
Concept Development																								
Mission Computer Integration																								
Integrated Photonics																								
CNI Integration (Link/CEC.IFF/SATCOM)																								
ES System Integration																								
Q70 Console Integration																								
IRST Integration																								

PMA-231 AH SD&D Program Milestone



Three Phases

- Integrated Test Plan
  - Phase I: Subsystem I&T at Contractor Facility
    - Government witnessed
  - Phase II: Makaha Ridge I&T – Contractor
    - Government witnessed

- Final Test Plan -- Makaha Ridge – Phase III
  - Real-Time Demo
    - Demonstrate system control, beam forming, data collection
    - Record data
      - with / without jammers, with / without controlled air targets
  - Real-Time Demo
    - Final RTB inspection
    - Initial setup & calibration demonstrations & tests
    - Initial operating demonstrations & tests
      - Data Collection, Real-Time Processing
    - Controlled aircraft demonstrations & tests
    - Post-Mission demonstrations & analyses